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For Industry
and Commerce

SAVING MONEY IN TRANSPORTATION AND DELIVERY 7

Energy, Mines and Resources Canada
Office of Energy Conservation

Énergie, Mines et Ressources Canada
Bureau de la conservation de l'énergie

88-03076/

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E1-77-14
© Minister of Supply and Services Canada 1980
Cat. No.: M91-2/7-1980E
ISBN 0-662-11153-2

Published under the authority of
Minister of Energy, Mines and Resources,
Government of Canada

SAVING MONEY IN TRANSPORTATION AND DELIVERY 7

Saving money through Transportation and Delivery

Introduction:

Transportation of materials and people consumes a large percentage of the fossil fuels used in Canada every year. As such a major energy consumer, it is naturally a major target area for industrial energy conservation programs.

This booklet attemps to cover a number of in-plant and ex-plant subject areas which are relevant to the industrial company intent on reducing its energy bills in the transportation sector. Particular emphasis is given to operation and maintenance of company car and truck fleets.

Transportation . . . a top priority

As the costs of both diesel fuel and gasoline climb over the dollar per gallon figure, saving energy in transportation and delivery is becoming a top priority.

The price of fuel is now more than double what it was in 1971. Fuel costs account for about 7½ per cent of the total operating costs in any trucking operation — not a huge figure, but a significant one because fuel consumption can be controlled more easily than many of the components of trucking costs. These costs have a direct relation to company profits, and if lowered, can reduce the impact of inevitable further increases in the price of fuel.

The most visible energy conservation measure is the air deflector, and more and more of these devices mounted on cabs to streamline vehicles are appearing. However, the largest single saving can be achieved by substituting diesels for gasoline engines. Other methods include better driving habits and use of fan clutches and radial tires.

And savings in transportation and delivery are not limited to trucking. Improvements also can be made to company car fleets, and in-plant measures such as lift truck maintenance and air locks on loading dock doors can be very effective energy conservers.

Transportation accounts for one quarter of Canada's energy usage. This figure includes all modes including private cars, buses and trains, but use of cars and trucks for transportation and delivery in the industrial sector constitutes a large portion of this consumption. As a result, the potential volume of savings is significant and should be actively pursued.

A look around the plant is all it takes to identify potential savings in relation to lift trucks and loading docks. And an examination of car and truck fleets will find still other ways to save energy. Both areas offer a real opportunity to make mileage with energy conservation.

In-plant operations

Of the transportation-related measures which can be carried out in Canadian plants, among the most significant are those related to increasing lift truck fuel economy.

Lift truck operations

Hidden from sight, the motors in an electric lift truck are generally assumed to be protected from hazards like extensive exposure to abrasives, moisture and accidental blows. Yet, they are subject to their own brand of abuse through operating conditions and techniques and maintenance practices.

Most owners pay attention to battery maintenance, the hydraulic systems and the masts. But practical tips on using and maintaining a DC traction motor and a pump motor in an electric vehicle are in order. Naturally, lift truck pump drive and propulsion motors will deliver better fuel economy if they are well looked after. Some of the tips for better maintenance are detailed on the following page.

Off-peak charging of lift truck batteries is another way to save on energy bills. Often, battery chargers are started at the beginning of the first work shift, a practice which incurs an additional electrical load during a peak demand period, resulting in extra demand charges from the electrical utility. By charging batteries during

Tips on Lift Truck Maintenance

Item	Do This	Don't Do This
Brushes	Inspect periodically and replace brushes before damage to commutator.	Allow to wear to condition where shunts or rivets rub on commutator.
	Replace brushes that have loose shunts.	Use brushes with loose shunts either tamped or riveted.
	Replace brushes with defective shunts or that have loose terminal connectors. Always inspect and tighten brush terminal connections to cross connectors.	Use brushes with oxidized shunts due to excessive heating or defective shunts or shunt terminal connectors.
	Replace with new brush grade as recommended by brush and/or the motor manufacturer.	Replace same brush grade that exhibits rapid brush wear resulting in heavy carbon deposit on motor interior.
	Always use brush grade as recommended by the manufacturer or use a grade that has proven field performance. Replace all brushes at the same time.	Never mix brush grades on motor during brush replacement.
Terminals	Inspect, clean and tighten all terminal connections during every routine inspection.	Don't allow external or internal cable connections to become loose — Results in burnt terminals due to excessive heating and eventually causes motor failure.
Commutator	Remove motor and check for damage. Commutator should be turned, cleaned and undercut. Mica slivers must be removed.	Allow commutator to become pitted, grooved, out of round, rough surfaced or discolored.
	Inspect and repair commutator or install new armature.	Allow operation with high or low commutator bar or bars.
Brush Springs	Check spring pressure during routine inspection, replace if necesary.	Don't operate motor with bent, discolored, badly corroded or discolored springs. Could result in improper brush pressure and cause poor commutation, excessive brush wear due to mechanical vibration or electrical wear.
Fans	Check fan during routine inspection and replace if necessary.	Permit motor operation with fan loose or broken blades. Fan loose on shaft could cause damage to field coil insulation or excessive noise or vibration. Broken blade or blades could result in insufficient air flow, excessive motor heating.
Motor Shaft Seal	Check for evidence of Transaxle lubricant in motor interior during routine inspection. If present, check seal and replace.	Permit motor operation with defective drive end shaft seal. Its purpose is to prevent transaxle lubricant from entering motor. Could cause insulation failure, poor commutation resulting in excessive sparking and rapid brush wear.
Motor Interior	During routine inspection remove and clean thoroughly. When cleaning use only solvents recommended for electrical equipment. Do not use cleaners containing silicones or chlorines.	Allow motor interior to become dirty from excessive carbon dust, lubricant, hydraulic fluid, dirt or other atmospheric contaminates. Could result in motor failure, or excessive heating — poor commutation, insulation failure.
		General: truck cleaning. Don't clean trucks with liquids or solvents containing silicones. Rapid brush wear could result.
Covers	Check — repair or replace during routine inspection.	Allow bent, broken or missing covers. Bent or damaged ventilating covers restrict air passage through motor and cause ground faults. Insufficient air could result in excessive heating — motor failure. Missing covers: purpose of covers it to protect motor from foreign objects — screws, nails, stones, dripping battery acid, etc. from getting into motor. Missing covers offer no protection to motor interior and could cause severe electrical or mechanical damage.
Motor	Check truck maintenance manual for frequency and methods for proper maintenance. Keep accurate and continual records to assure maximum motor reliability.	Don't rely on habit or memory for routine motor maintenance schedules.

the second shift, when peak demand is much lower, money can be saved on electrical bills. One General Motors plant saved almost $10,000 in one year (see case history). The same principle can be used for other energy consuming activities which need not be carried out during peak demand periods. Peak load schedulers or "load shedders" should be investigated to make further use of this concept.

Kimberly-Clark, for example, has found in tests that propane powered fork lift trucks, equipped with catalytic mufflers and capacitor discharge electronic ignition systems require less maintenance, less downtime, less fuel and give better reliability than standard propane-powered units. But for these results to be achieved, the trucks should be tuned with diagnostic ignition analyzers and carbon monoxide gas analyzers. Among the conclusions of the tests was that it is possible to reduce fuel consumption up to 20% and to reduce maintenance material and labor costs using the diagnostic equipment on a regular maintenance program. Early results indicate that 15-20% savings in material and labor costs were possible.

In addition to energy savings, the tests showed that heating and ventilation costs in all of the firm's Canadian plants could be reduced, and that greater protection from fork truck exhaust emissions could be given to plant personnel.

Air Locks for Loading Doors

A substantial loss of energy occurs every time a loading door is opened to the outside during loading and unloading operations with no means of preventing heat escape from the building interior. This energy loss may be reduced by installing an air lock at the loading door.

A structure or device which prevents the unloading door from being directly exposed to the outside when open, air locks require quite a substantial capital expenditure — $20,000 for a door 20 ft. x 17.5 ft. And for any specific installation the savings obtained would vary widely depending on prevailing winds, length and severity of the heating season, the size of the opening, and the cost of energy for space heating (see case history for calculation of savings). In general, air locks should be considered for loading doors which are open frequently or for extended periods of time.

There are other ways to save energy in loading dock areas. Fixed walls, fireproof canvas or plastic curtains and other barriers can be used to limit access of cold air from loading and receiving docks to the plant or warehouse floor (see case history). Dock shelters can be installed on loading docks. They come in a variety of designs and can, under some conditions, pay for themselves in a single season (see case history).

Use of such barriers often means that heating equipment can be eliminated. General Motors disconnected five gas-fired door heaters when it installed a metal wall with two doors and weather curtains at the edge of its receiving dock. GM saved over $17,000 per year and the cost of improvement was only $2,100 (see case history).

Savings in use of cars

Many companies encourage their employees to buy small cars, ride to work in vanpools or carpools, or use staggered hours to save fuel. But the company can achieve even more energy savings when it is responsible for buying the cars used by its salesmen and other employees.

Du Pont of Canada, for example, expects to save $30,000 per year in energy at today's prices by converting all the cars in its fleet from large to intermediate-sized cars. As of October, 1976, there were 220 cars in the fleet and by December, 1976, 44% were intermediate-sized. The expected savings are about $160/car/year at the current price of gasoline, and this figure does not take into account the lower maintenance charges for smaller cars.

There are many things a company can do to save energy in its car fleet — but purchasing smaller cars with smaller engines and cutting down on such gas-guzzling features as air conditioning are prime.

URBAN FUEL ECONOMY TABLE*

Curb Weight (Lbs.)	Approximate Fuel Economy (Miles per gallon)	6000 Mile Fuel Cost (@ 85¢ per gallon)
1950	30	$170
2450	25.5	200
3200	20.5	249
3700	18.5	276
4200	16.5	309
4700	15.5	329

*Based on data submitted to Transport Canada by auto manufacturers as part of the emission control program.

The company can also encourage energy savings by making better use of its cars. Often, company vehicles are returned to a garage or lot at the end of the day to remain idle until the next morning. This capital equipment can be more effectively used by allowing employees to drive the vehicles home at night if they form carpools. Such a program is already operating at the Arkansas State Highway Department in Little Rock, Arkansas. Here, state vehicles carrying a minimum of three carpool riders are permitted to be taken home at night. (See also book #8.)

Saving energy in trucking

The majority of changes to save energy in industrial transportation and delivery involve trucks. And without any expenditure, routing and load optimization are prime considerations — that is, to consolidate routes so that trucks are utilized as fully as possible, and so that fewer trips are needed. Getting more payload into fewer trips reduces the number of times the weight and frontal area of a truck are transported, and therefore cuts the amount of fuel needed to move each ton of freight. The table shows the results of operating at various gross weights in order to move 6,300 tons of freight over a 200-mile route.

GCW (lb)	50,000	55,000	60,000	65,000	70,000
Payload (lb)	25,000	30,000	35,000	40,000	45,000
Number of trips needed	504	420	360	315	280
Fuel Used					
Miles/gallon	4.64	4.55	4.45	4.36	4.28
Gallon/trip	43.20	44.00	44.80	46.00	46.80
Total gallons	21,773	18,480	16,128	14,490	13,104
Gallons/ton of freight	3.46	2.93	2.56	2.30	2.08

*Based on information from Mainstem, Inc.

For internal trucking operations, routing control is strictly an internal consideration and should encounter few barriers. CGE, for instance, has done much work to assure that trucks operating between Toronto and Montreal are fully loaded for backhaul whenever possible. "Deadheading" wastes fuel.

For common carriers, however, routing control involves taking a look at where the customers are, and deciding whether certain routes can be combined; and, in some cases, whether people can do with deliveries less frequently.

For such a program to work to its fullest extent, customers must be informed of the reasons for the change, and negotiations must be made with customer management. Less frequent service often promotes better utilization. But, given the competitive nature of business, it is impossible to give a customer slower transit times than he demands. Consultation and a reasoned approach in many cases will establish that a somewhat lower standard of service will be acceptable in non-critical areas if the reasons are clearly explained.

Among the important tips for routing are the following:

- Consider consolidating routes. Avoid unnecessary trips. Eliminate overlaps.
- Attempt to discourage or eliminate special deliveries of orders.
- Work with retail outlets to eliminate special delivery deadlines.
- Consider cutting delivery frequency where possible.
- Consider structuring routing on a seasonal basis.
- Ensure optimum vehicle load.
- Combine routes for vendor and sign maintenance and similar services.
- Consider consolidation of sales, complaint service calls, and cooler delivery for most efficient truck usage.
- Consider using radio-controlled vehicles to change routing while on road.
- Examine warehouse locations to improve delivery efficiencies.
- Increase route volume per truck where possible.
- Schedule delivery times to avoid rush-hour traffic where possible.
- Work with local officials regarding restricted parking which affects delivery efficiency.

Driver Training

One of the biggest variables in conservation of energy in trucking is driver performance. If drivers make a habit of "jack-rabbit" starts or leave engines idling for long periods of time, many of the savings gained through other measures will disappear.

And one of the worst problems is long periods of idling. Particularly for gasoline engines idling results in considerable fuel wastage. Raw fuel may wash lubricating oil off cylinder walls and dilute crankcase oil so that all the moving parts of the engine will suffer from poor lubrication. So it's clear — when not using the engine, drivers should be instructed to shut it down.

Strange as it may seem, idling does not even make a contribution to keeping an engine warm in cold weather. In fact, one engine manufacturer has proved that if the engine is shut down in cold weather, it will remain warmer after one hour in the shut down position, than it would running at 800 or 1,000 rpm — with the added advantages of major fuel savings, no noise and no air pollution. Use of auxiliary starting equipment, discussed later is vastly preferable to leaving the engine idling.

Some other tips for drivers include:

- Staying 200 rpms under the governor maximum to save fuel.
- Not hitting the governor with every shift. It takes extra fuel to go to maximum rpm with every shift.
- Keeping a light foot on the accelerator and brake pedals to conserve fuel — not hotrodding or sliding to a stop.
- Gearing down when necessary, rather than lugging. Lugging the engine takes extra fuel, and it increases the likelihood of early overhauls and breakdowns on the road.
- Checking tire pressure. Keep your tire pressure up, since it's easier on the tires and saves fuel.
- Preventing spillage. Make sure extra fuel isn't spilled when you refuel. Don't top the tank! Keep your fuel cap tightened so that you don't lose fuel through evaporation or spillage.
- Staying alert and rested. Drive safely and conserve fuel. A tired driver is erratic, doesn't shift gears when he should, and fails to hold his speed. Driving this way uses extra fuel.
- Keeping the engine tuned. An efficient powerplant burns less fuel.

One further tip — stick to lower speeds. The speed limit has been lowered to 55 mph in some provinces already, but even where the speed limit is higher, slowing down makes sense. The table shows the kinds of fuel savings that can be made in a trucking operation using a 65,000 lb GCW, 13.5 van tractor/semi-trailer combination.

Engine Type	Geared Speed at 2100 rpm (mph)	Cruise Speed Limit (mph)	Engine Speed at Cruise (rpm)	Average Speed (mph)	Fuel Economy (mph)
A	59	No limit	2100	54.9	4.51
		55	1950	50.9	4.86
		50	1780	47.1	5.10
C	64	No limit	2100	59.5	4.26
		60	1970	56.9	4.60
		55	1800	52.0	4.93
B	70	No limit	2100	64.7	3.85
		65	1950	60.4	4.35
		60	1800	56.9	4.80

Reducing speed from 65 to 55 miles per hour will cut air resistance by 25% and will also reduce rolling resistance by 14%. This could result in a fuel saving of more than 15 percent.

There are three major approaches to making drivers slow down, each with its own advantages and drawbacks:

- using a road speed governor
- using a tachograph to enforce a fleet speed limit
- motivating the driver to want to maintain lower speeds.

Motivating the drivers, is generally the most successful approach. Share truck mileage and fuel consumption data with drivers to encourage savings efforts.

Remember, driving slower is helpful only as long as the driver can make effective use of top gear. Below about 1800 rpm, the driver will drop back a gear and cruise at high rpm again.

The Right Truck for the Job

One way to ensure efficient and economic operation is to make sure the truck is specified correctly. Often the engine is too small, resulting in failure through overwork since it is operating at better than 80% of capacity for half the time and 100% for the remainder.

Another common mistake is retiring power units purchased for highway operation to city use.

Such trucks are not powered or geared correctly and can't be expected to perform properly.

Unsuitable specifications affect overall operating costs, including fuel consumption. Make sure you have chosen the right truck for the job.

Preventive Maintenance

Good preventive maintenance is one of the fundamentals of fuel economy. Make available and encourage mechanics to use the shop manual when tuning a truck. A well-thumbed manual can be a good indication of superior vehicle performance.

Adherence to a regularly scheduled program of preventive maintenance is the best way to prevent major breakdowns. The costs of the effort are minor in relation to the benefits. It doesn't require a professional mechanic to do some of the simple jobs such as changing oil and filters, but neglect in these areas can severely shorten the life of your fleet. Sixty-days, in fact, is a good interval between tune ups. Post a check-board in a visible place detailing what work is supposed to be done on what vehicles and when. The results in better fuel economy are sure to justify the time expended.

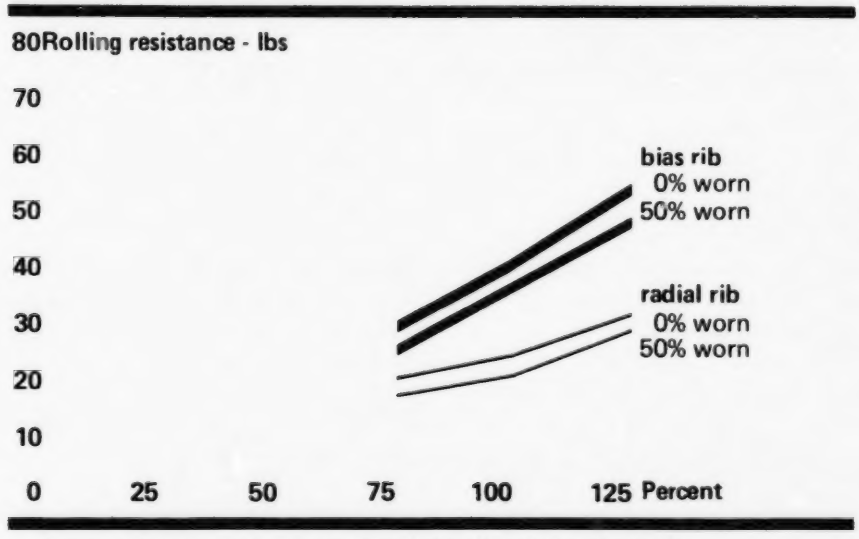
Radial Tires for Energy Conservation

Radial tires offer great potential for energy conservation in terms of fuel consumption, tire wear, improved retreadability and reduced downtime. Radial plies eliminate shear stresses and lower rolling resistance resulting in lower power consumption, lower operating temperatures and lower spring rates. The difference is due to the purely radial direction of the body ply cords which perform the load carrying function as opposed to the diagonal crisscross pattern of the conventional bias ply tire. The addition of belts to the carcase or body gives added stability to the tread and improved puncture protection.

Other advantages of radial tires:

- Longer wear, resulting from the more rigid construction which produces significantly less tread movement on the pavement. Tread life is 48 percent longer than the standard rib tire, and 10 percent longer than cross bar.
- Cooler running, resulting from reduced hysteresis loss and lower power consumption.
- Better impact penetration, resulting from the improved construction. Reduced cutting and puncturing reduces downtime 50-75 percent and improves the percentage of carcases available for retreading.
- Equal or better traction due to reduced tread deflection.
- In most cases handling is improved, although some drivers dislike handling characteristics on gravel roads.
- Reduced shoulder tearing.

Rolling Resistance of Bias Rib and Radial Tires



Percent of maximum loading per Tire & Rim Association Yearbook.

Fuel Savings with Radial Tires: Fleet Experience

Fleet	Type of Operation	Fuel Savings
A	Long Haul, General Freight	6% fuel savings with tractor, 10% with tractor and trailer
B	Long Haul, General Freight	5-9% fuel savings with tractor and trailer
C	Long Haul, General Freight	4% savings with tractor
D	Long Haul, General Freight	Increase of .2 mpg or 4.4% (assuming 4.5 mpg)
E	Long Haul, General Freight	8.6% fuel savings
F	Long Haul, Specialized	4-5% fuel savings with tractor
G	Long Haul, General Freight	Increase of .2 mpg or 4.4% with tractor (assuming 4.5 mpg)
H	Long Haul, Bulk	Increase of .5 mpg or 11.1% with tractor (assuming 4.5 mpg)
I	Long Haul, General Freight	Combined increase of .3-.4 mpg or 6.7-8.9% (assuming 4.5 mpg) with both radials and fan clutches.
J	(Private), Food Store Delivery	Little fuel savings
K	(Private), Food Store Delivery	Gain additional 20 hp, derate engine accordingly to save fuel

Source: Communications with fleet operators.

Many tests of the differences in fuel consumption caused by use of radial tires, has found an average 6% improvement in fuel consumption compared with the bias ply tire. In certain applications such as buses, this improvement reached 12%.

The one major disadvantage to the use of radial ply truck tires is cost. But while the initial outlay can be nearly 25% higher, the increased initial and retread mileage resulted in a 37% increase in the value per truck due to radials. This is in addition to the 6% improvement in fuel consumption.

Gasoline or Diesel — Which Is Best for You?

Diesel engines offer many advantages in terms of energy conservation, and as fuel prices rise, they are becoming more and more popular. Vastly superior fuel economy, longer life, less maintenance and less downtime are among the benefits diesels offer. But offsetting these advantages to some extent are the higher costs of diesels — the price differential can be $4,000 to $10,000 more than gasoline-powered trucks.

The fuel savings gained by using diesel engines can be quite impressive — as much as 50% under stop-and go urban driving conditions and 20% on the road. These savings are even more notable when one considers that the price of diesel fuel is often lower than gasoline, and that diesel fuel has 14,000 Btu more energy per gallon than gasoline.

Another significant advantage of the diesel engine is the money it saves in terms of

maintenance and availability. It is hard to place a dollar value on equipment breakdown, but in some operations, loss of income can amount to more than the value of the equipment causing the delay, making even a minor breakdown expensive.

One of the reasons for fewer breakdowns is that components of a diesel engine are normally built of heavier material, are more metallurgically perfect and are designed to withstand more abuse than the gasoline engine. Another reason is that in nine out of ten cases, a gasoline engine road failure will either be caused by a malfunction in the electrical ignition system or because the engine has overheated. Diesel eliminates the first problem because it does not require external ignition systems. The diesel is not troubled with overheating because diesel exhaust temperatures are not nearly as high as those of gasoline engines and because the diesel does not have to burn extra fuel to cope with the vacuum effect caused by the carburetor in gasoline engines.

Preventive maintenance costs about half that of the gasoline-engined vehicle. There are longer intervals between oil and filter changes and overhauls since engine life is similar to chassis life in relatively low mileage applications. And there is less unscheduled downtime.

An example of just how economical a diesel engine can be, occurred at Smith Transport in North Bay, Ontario. Driver René Ouellette and mechanic John Sheridan ran 100,000 miles at an operating cost of 3.4 cents per mile (excluding fuel and tires) with a 1973 tractor with a mid-range diesel engine. The truck was on a steady run, doing between 115 and 200 miles a day with little city driving.

There are some disadvantages to the diesel engine, besides the higher initial cost. Diesel engines have had a reputation for being dirty in the past, but problems with emissions have largely been overcome. Caterpillar Tractor Company has made studies showing that diesel truck engines with precombustion chambers emit the lowest level of contaminants of all truck engines; and that regular diesel truck engines are relatively clean — certainly well below the stringent U.S. government regulations.

One disadvantage that must be faced is the need for auxiliary starting aids (larger batteries, gasoline-fired hot boxes, ether or glow plugs, or electric block heaters) in cold weather operation — a factor to be considered in our Canadian climate.

One of the major criteria when deciding whether to use diesels is mileage — if your trucks travel extensively you can probably justify the cost of diesel engines. Other factors include load weights and speeds — but in any case, diesels are an energy-saving option well worth investigating.

Aerodynamic Drag Reduction Devices

Aerodynamic drag reduction devices, such as wind deflectors are intended to lessen that part of the engine's total power requirement devoted to overcoming wind resistance. And while there is often some question of manufacturers' claims for potential fuel savings, virtually everyone agrees that aerodynamic drag accounts for a major portion of a truck's horsepower requirement when it is moving at highway speeds.

Air resistance is caused by the pressure drag created by the movement of a flat surface perpendicular to an air stream. The airstream hitting a moving rig is deflected to the sides and over the top of the vehicle. And in tractor/van-trailer combinations, one of the major causes of air resistance is the sharp change in the shape of the vehicle at the point where the trailer begins. The airstream is deflected over the top of the cab, but hits the front of the trailer and falls into the gap, creating turbulent air motion. This turbulence in the gap increases the air resistance and therefore the power requirement and fuel consumption of the engine. Another more turbulent area is at the rear of the trailer created in the wake of the moving vehicle.

There are several types of devices available for aerodynamic drag reduction. These include: 1) wind deflectors mounted on cab tops to deflect air flow over the top of the van or trailer; 2) vanes which turn the airflow around trailer corners; 3) rounded trailer corners and fairings mounted on the forward flat face of the trailer; and 4) gap fillers to reduce turbulence in the gap between tractor and trailer.

The table on the following page shows some of the devices on the market today, and the manufacturers' claims regarding performance.

Summary of Claimed Results of Aerodynamic Drag Reduction Devices

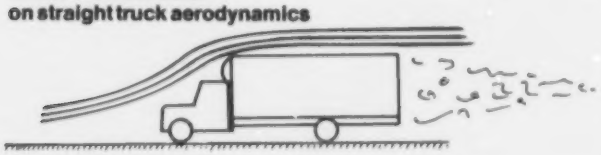
Company Trade Name	Type	Installation	Available	Estimated Cost	Drag Reduction Claim	Fuel Reduction Claim	Basis for Claims
Airflo	Deflector	Cab Top	Yes	$230-260[a]	11.14%	18-30% 10-33%	Road Test, NASA Road Test, Bendix Track Field Tests by Users
Airshield	Deflector	Cab Top	Yes	$215	16-24% 11% 7.6-17%	6.7%	Road Test, NASA Wind Tunnel Test, Purdue Road Test Aerovironment
GMC "Drag-foiler"[a]	Deflector	Cab Top	Yes	$400	up to 35%	9%	Wind Tunnel Test, General Motors Corporation
Windbreaker	Deflector	Cab Top	Yes	$140	N/R	7-11.9%	Field Tests by Users
Uniroyal Air Deflector	Deflector	Cab Top	Yes	$235-310[a]	20%	10%	Road Test by Manufacturer
S^3 Air Vanes	Turning Vanes	Trailer Front Edges	Yes	N/R	6-25% 2-3%	4.2-8.6%	Wind Tunnel Test, GALCIT Road Test, S^3 Road Test, NASA
Blair-Lefler	Turning Vanes	Cab Top	No	N/R	11%	3-7%	Road and Wind Tunnel Test, Wichita State University
Vehicular Stator	Turning Vanes	Cab Top (Pickup Only)	Yes	$275	N/R	12-27%	Road Test, University of Oklahoma
Trailer Duct	Air Duct	Trailer Top	No	N/R	47%	N/R	Wild Tunnel Test, University of Utah
Aeroboost	Rounded Corners Top lip only Complete Set (top & 2 side lips)	Trailer Front	Yes	$124 $295	10% 34.6%	4% 17.3%	Road Test, Aerovironment, Inc.
Nose Cone	Rounded Fairing	Trailer Front	Yes	$265-295[a]	11%	6-11% 7-37%	Road Test, NASA Road Test, Aerovironment Field Tests by Users
Payne Inc.	Edge Fairing (Retractable)	Trailer Vertical Corners (Front)	No	N/R	N/R 50%		U.S. Marine Corps R&D Program for Amphibious Vehicles. 2-D Water Table Test
Aerovane	Gap Filler (Retractable)	Cab Mounted (Tractor/ Trailer Only)	No	N/R	19%	6-7%	Wind Tunnel, Vanderbilt University Road Test, NASA Road Test, Georgia Tech
Vortex Stabilizer (Used with Airshield)	Gap Filler	Trailer Front	Yes	$90		3.62%	Road Test, Molded Materials Company
Vehicle Space Closing Means	Gap Filler (Inflatable)	Inflatable Device; Attached on Rear of Cab	N/R	N/R	N/R	13%	Road Test by Developer

N/R = Not Reported
[a]Updated by communication with company representative or from information in company brochures.
Source: Innucept, Inc., *An Evaluation of Truck Aerodynamic Drag Reduction Devices and Tests*, for the National Science Foundation, June 1975.

Other recent tests in the National Research Council's Low Speed Aerodynamics Laboratory confirm that all eight of the truck and trailer add-on devices tested reduce wind drag to some extent; and that all of them would pay for themselves in fuel savings inside of a year. The tests also revealed that there is no wind drag reduction device that outperforms the others in every set of circumstances; that direction and wind velocity, weight, configuration and travel speed of the payload carrier all play a major role in the performance.

Interestingly enough, parallel road tests conducted for the Department of Energy, Mines and Resources and Transport Canada showed that use of air deflectors on straight trucks resulted in a significantly higher percentage fuel savings — 9-14% as opposed to the 4-5 percent achievable on tractor trailer combinations. It is worth stressing that manufacturers' claims of attainable fuel economy are often exaggerated. The chart on page 10 shows experience with air deflectors on semi-trailers in the U.S.

Effect of air deflector on straight truck aerodynamics



The fuel economy improvement is in the neighbourhood of 0 to 5%, and the cost of these devices ranges from $200 to $350. As the NRC tests show, there are no hard and fast rules as to which aerodynamic drag reduction devices are the best — that depends on the type of truck and its use.

Use of Double Trailers on Trucks

As payload weight increases, fuel economy on a productivity basis also increases, since as the gross vehicle weight increases, the rate of increase in fuel consumption per mile is less than the rate of increase in weight. Load space can be increased by using longer or multiple trailer combinations within the appropriate length limit. A typical single 40 ft. semi-trailer has a volume of 2,700 cubic feet; two 27 ft. trailers have a combined volume of 3,600 cubic feet; three 27 ft. trailers have a combined volume of 5,400 cubic feet; and two 40 ft. trailers have a volume of 5,400 cubic feet. Doubles, therefore, provide one-third more cube than singles, while triple and double 40s provide 100% more capacity than singles.

The potential savings to be realized by the use of doubles and triples versus singles for both high and low density freight are shown in the table on the following page. These data were derived from computer simulations of typical tractor/trailer travel over selected western U.S. routes. Two observations are apparent: that triples provide much greater fuel savings than doubles; and that savings are greater in the case of low density freight than for high density cargo. Obviously, provincial length and weight regulations may limit the applicability of doubles and triples as an energy conservation measure.

Projected fuel savings have also been made on the basis of road tests performed by a motor carrier. The results show a 21% fuel consumption advantage using triples instead of doubles and a 15% fuel savings realized by using double 40 foot trailers as opposed to a single, 40 foot semi-trailer. The latter result corresponds to operations involving high density cargo in which the maximum weight limit is reached by the combination.

Automatic versus standard transmissions

Almost all fleet operators engaged in line-haul activity seem to reject automatic transmissions. They feel that no fuel savings are realized through their use and the benefit of reduced shifting is less striking when compared to a six-speed manual transmission coupled to a high-torque engine. The higher cost of the automatics — $3,800 for a road tractor compared to the manual six-or ten-speed cost of about $800 — is a factor discouraging their use. Some companies have tried automatic transmissions, but none have adopted their use for the fleet as a whole.

However, there is some acceptance for automatic transmissions in local pick-up and delivery operations where the shifting of gears is considerable. Evidence from refuse haulers, short-haul operators, and furniture haulers indicates average savings of between 6 and 10% can be achieved through use of automatic transmissions.

The manual or semi-automatic manual transmissions have marginally better mechanical efficiencies. However, it takes a very skilled, constantly-fresh driver to take advantage

Wind averaged drag coefficients and estimated fuel usage at 55 mph for data averaged over three tractor-trailer separations (33 in., 53 in., 73 in.).

(COE tractor) (Conventional tractor) (Straight truck)

	Configuration	White Freightliner WFT8664 GCVW = 70,000 lb.			I.H.C. 1800 Loadstar GCVW = 55,000 lb.			I.H.C. 1600 Straight Truck 20 ft. Box, GVW = 18,000 lb.		
		$W.A.C._D$	MPG	Fuel Savings Per Year**	W.A.C.	MPG	Fuel Savings Per Year**	$W.A.C._D$	MPG	Fuel Savings Per Year**
	Baseline	0.98	4.58	—	0.94	5.32	—	0.88	8.62	—
TRAILER MODIFICATIONS	Square corners	1.07	4.36	- 1102	1.31*	4.75	- 2240	—	—	—
	Refrigeration unit	0.94*	4.69	490	0.91	5.42	354	—	—	—
	Bevelled nose	0.91+	4.77	856	0.93+	5.35	118	—	—	—
	12 in. Radius — front top, side cors.	0.91	4.77	856	0.84*	5.68	1179	—	—	—
	½ cylindrical nose	0.88+	4.85	1225	0.84+	5.68	1179	—	—	—
	Rounded ½ cylindrical nose	0.86+	4.92	1470	0.80+	5.83	1651			
TRACTOR MOUNTED DEVICES	Airglide	0.91	4.77	856	0.92	5.39	236	0.86	8.78	31
	Airshield (old setting)	0.91	4.77	856	0.90	5.46	472	—	—	—
	Airshield (new setting)	0.86*	4.91	1470	—	—	—	—	—	—
	Airshield (old setting + Gap Seal)"	0.86	4.91	1470	0.86	5.60	943	0.73	9.95	232
	Airshield (new setting + Gap Seal)"	0.82*	5.03	1960	—	—	—	—	—	—
	Uniroyal (old pin setting)	0.90	4.80	980	0.92	5.39	236	0.78 ‡	9.46	155
	Uniroyal (new pin setting)'	0.86	4.91	1470	0.90	5.46	472	0.75 ‡	9.75	201
	G.M. Dragfoiler #	0.87	4.89	1347	—	—	—	—	—	—
	G.M. Dragfoiler # (+ Gap Seal)"	0.83	5.00	1837	—	—	—	—	—	—
TRAILER MOUNTED DEVICES	Vortex stabilizer (+ airshield, old setting)	0.90	4.80	980	0.88	5.23	708	—	—	—
	Nose Cone	0.87	4.88	1347	0.83	5.71	1297	0.68	10.48	309
	Aeroboost ¢	—	—	—				0.76	9.65	186
	S^3 Airvane (top only)	0.92*	4.74	735	0.87*	5.56	825	0.80 ‡	9.28	124
	S^3 Airvane (top + sides)	—	—	—	—	—	—	0.69 ‡	10.37	294

NOTES: WAC_D Wind averaged drag coefficient

** Based on 100,000 mi. for combinations and 15,000 mi. for straight truck (Imperial gallons)

* Data taken at 53 in. separation only

+ Data taken at 21 in. separation only

Modified version constructed for the Freightliner and not the optimum, but close to it.

¢ An approximation using ½ cylindrical cover fairings.

‡ Estimate based on limited data

" Gap Seal is in experimental stage only, not available for sale

Angle of deflector readjusted as a result of NRC wind tunnel tests

Fuel Savings with Fan Clutches: Fleet Experience

Fleet	Type of Operation	Fuel Savings
A	Long haul, general freight	2.5%
B	(Private) Food store delivery	5.0%
C	Long haul, specialized	1.5-5.8%
D	Long haul, general freight	4.5-5.0%
E	Long haul, general freight	4-6%
F	Long haul, general freight	Increase of .2 mpg or 4.4% (assuming 4.5 mpg)
G	Long haul, general freight	Combined increase of .3-.4 mpg or 6.7-8.9% (assuming 4.5 mpg) with both fan clutch and radial tires.
H	Long haul, bulk	4.3-16.7%

Source: Communications with fleet operators.

of this, and show improvements in trip times and improved fuel economy. In reality, the lower general level of skill and the effects of fatigue during an eight-hour shift often result in less efficient operation such as lugging or overspeeding the engine due to incorrect gear engagement. There are also less tangible effects such as higher rates of wear on transmissions, clutches and drive axles.

The automatic can decrease the need for a skilled driver, maintain a driver's level of efficiency throughout his shift, enable him to concentrate on the road, protect the engine and drive train from abuse and yield better trip times in congested stop-and-go conditions.

Another advantage can be better utilization of automatics. Smith Transport reported that in 1973 it had ten new automatic vehicles for city operation, and thirty manuals. All vehicles otherwise had identical specifications. Recent records indicated an increase of approximately one-third in the automatic vehicles' utilization factor. One operation in Montreal averaged 35,000 miles versus the manual's 22,000. Thus, a reduction in fleet size due to use of automatics may be possible.

Fan Clutches

Cooling fans don't have to operate for the entire time an engine is running to fulfill their function. In fact, most of the time the ram air created by the vehicle's movement is sufficient to cool the engine. Installation of a demand-actuated fan drive system, popularly known as the fan clutch, can save a good deal of energy by ensuring that the fan runs only when needed.

There are three kinds of fan clutches on the market:

The simple air-activated on/off clutch. With this type, the fan is either fully engaged or fully disengaged. Some are engaged by air and disengaged by means of a spring, while others are engaged with a spring and disengaged by air. This type of clutch has the greatest potential for fuel savings since the fan is completely disengaged when cooling is not needed. It is also the simplest and is very easy to repair; however, it can impose severe shock loads on fan belts and bearings when engagement takes place instantaneously, and the sudden power loss and increased noise level can be annoying to the driver.

The viscous drive system. This system results in a variable fan speed that is neither completely engaged nor disengaged. The clutch provides torque for the fan by the shearing action of silicone fluids between the input and output members of the drive system. Viscous drive has the advantage of being completely self-contained with no connections to the vehicle's air supply or cooling system, and it is the least expensive to install. But, since it does not disengage completely, horsepower savings, and therefore fuel savings, are less than those of the on/off clutch. The viscous fan clutch maintains a variable fan speed over a range of 45 to 90% of input speed; however, because the maximum air flow is still less than manufacturer's design, retrofitting may require an adjustment of the drive pulley ratios or installation of a larger diameter fan to protect the engine at times when maximum cooling is required.

The modulated fan clutch. This provides a variable fan speed but also the complete lock-up as in the case of the on/off fan clutch. The sensors here operate on the basis of expansion of melting wax. The wax pellet is sensitive to engine coolant temperature, and as the temperature changes, the valve changes the air pressure which provides variable fan speed. Another modulated fan clutch uses a temperature-sensitive wax pellet to control mechanical pressure to the fan directly. Either system provides the most accurate control of fan operation with variable fan speed provided over the range of complete lock-up to 10 to 20% of input speed. However, this type of clutch is the most complex of the three designs, has a greater chance of failure, and is the most expensive.

Fan clutches do offer great potential for savings, since studies show that the fan is required for less than 10% of the time the engine is running. Of course the savings are not as great for a heavily loaded vehicle engaged in slow speed, stop-and-go driving or climbing steep hills in hot weather — since all these factors affect the need for cooling. But a year-long test involving a large unit and an on/off fan clutch, hauling over mountainous western Canadian routes, showed that fan hours as a percent of total engine hours ranged from 0.13% in January to 8.62% in July. And, with the exception of July and August, the average monthly percentage of fan operation never reached more than 2.1%.

The fuel savings realized by use of fan clutches range from 3 to 10% according to a U.S. Department of Transport/Environmental Protection Agency study, with long-haul carriers expected to realize maximum savings of 7 to 10% and local trucks at the bottom of the scale with savings of 3 to 7%.

Prices for fan clutches range from $100 to $500 and fleet experience has concentrated on retrofitting existing units. However, the cost of the fan clutch specified on a new purchase is about $100 less than the cost incurred by retrofitting.

Fan clutches also reduce the vehicle's noise level. Actually, for many U.S. fleets, the fact that fan clutches enable trucks to meet government noise levels is a major incentive for installation.

A major disincentive is that reliability and durability are sometimes questionable. In some cases, the engineering is beyond the capability of the user. And in some retrofit applications, extensive alterations and adjustments to existing cooling systems must be made in order to install the fan clutch system in place of the constant drive unit. If the user does not possess the necessary knowledge, insufficient cooling and engine failure might result. Another cause of increased downtime might be extreme shock loads on the fan belts and bearings when the clutch instantaneously engages during over-the-road operation.

Despite these purported disadvantages, Smith Transport has used fan clutches successfully, and the company reports that it can get an extra 17 hp from rigs using the on/off fan clutch system. This gain in horsepower allows the fuel supply to the engine to be cut back by a full five percent and still maintain satisfactory highway performance. From this and other case history evidence, fan clutches are well worth investigating.

Automatic radiator shutters are one of the best devices for controlling engine temperature within the fairly narrow recommended range. This is not significant from a fuel economy point of view, but it will save money by adding to engine longevity.

Engine and Drive Train Modifications

It's hard to make any generalizations regarding engine and drive train modifications — such is the wide variety of components on vehicles

today. In addition, each component is interdependent so that changes to one may require adjustments to others in order to maintain adequate performance. And, because of these inter-relationships, it is hard to isolate and ascertain impacts of modifications on fuel economy.

While retrofitting can be very effective in other areas of energy conservation, its applications in this area are limited. Modifications to engines in existing units can achieve fuel savings, but usually at the expense of performance. And though many of the measures may appear inexpensive in themselves, they may require substitutions or alterations to other equipment such as transmissions or drive axles. These alterations are generally quite costly.

New "fuel economy" engines and matching drive train components are available on new vehicles at little or no additional cost above the standard engine options, and these new engines have been improved so that fuel savings are realized together with improved vehicle operation performance.

Possible modifications to engines and drive trains include the following:

Derating engine horsepower. This measure can improve engine longevity, reduce maintenance cost and save fuel in cases where there is an excess in power above that required for the vehicle's operation. Derating the engine involves recalibrating the fuel injectors to deliver less fuel than that stipulated in the original horsepower rating. Power should not be derated to the point where geared cruise speed cannot be maintained since the amount of shifting required will increase. A disadvantage is lower performance capabilities and increased trip times.

Derating is most effective when used in conjunction with radial tires, fan clutches and aerodynamic drag reduction devices — ensuring that power gained from these measures is not misapplied elsewhere. And since power requirement is reduced along with power availability, the difference in performance is not as great.

A computer simulation has shown that for a 70,000 pound tandem tractor with a 12.5 foot high trailer and a geared speed of 61 mph at 2100 rpm, derating horsepower alone from 290 to 255 hp resulted in a 4.8% fuel savings but a 3.7% loss in trip time. However, with the addition of radial tires, fuel savings nearly tripled to 13.7% and travel time lost was only 0.2%.

Road Speed Chart for Selected Combinations of Engine RPM and Rear Axle Ratios

(miles per hour)

Engine RPM (hundreds)	Rear Axle Ratio										
	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7
16	51.3	49.9	48.6	47.4	46.3	45.2	44.1	43.1	42.2	41.2	40.4
17	54.5	53.0	51.7	50.4	49.2	48.0	46.9	45.8	44.8	43.8	42.9
18	57.7	56.2	54.7	53.4	52.1	50.8	49.6	48.5	47.4	46.4	45.4
19	60.9	59.3	57.8	56.3	54.9	53.6	52.4	51.2	50.1	49.0	47.9
20	64.1	62.4	60.8	59.3	57.8	56.4	55.1	53.9	52.7	51.6	50.5
21	67.3	65.5	63.8	62.3	60.7	59.3	57.9	56.6	55.3	54.1	53.0

Note: Road speeds shown for each gear ratio are based upon the transmission in direct gear and the ability of the engine to run at the rpm shown. There is no consideration for engine power, type of terrain, load or air resistance. This chart is based on tire size 10.00-20 tube tires (11.00-22.5 tubeless tires).

Source: Eaton truck speed chart from the Truck Components Group of Eaton Corporation.

U.S. government estimates show fuel savings due to derating of the engine to be about 2 to 5%.

Reduction of engine speed (rpm). Conventional diesel engines generally operate at a maximum of 2100 rpm at which point the governor limits the fuel flow to the engine. However, optimum fuel efficiency occurs around 1600 to 1800 rpm. If the governor is adjusted to reduce maximum engine speed, the driver is forced to operate the vehicle in a more fuel-efficient way. But the resulting reduction in road speed can cause additional shifting, and this means increased driver fatigue and increased wear on the drive train components.

As with derated horsepower, reduced engine speeds will maintain vehicle performance only if other components are appropriately altered. For instance, if the lower performance resulting from rpm reduction enables the vehicle to perform its task without alteration to the drive train, adjusting engine speed provides an economical way to conserve fuel. Benefits include lower noise levels, improved engine durability and reduction of maintenance requirements. Again, savings are maximized when power requirements are reduced by use of radial tires, air deflectors, etc. The chart shows the kind of savings that can be expected, and how savings are maximized by using radial tires.

Reducing the axle ratio. This reduces the engine speed needed to maintain a given road speed, and keeps the engine performing at a more fuel-efficient level. However, it also increases the amount of shifting required and can result in longer trip times. The savings gained by doing this are generally less than those achieved by reducing engine rpm — and range from 0 to 5%. The lower axle ratio must be matched with correct gearing and torque characteristics. Good fuel economy can be obtained if a 5 or 6 speed transmission is used so that the cruise speed can be maintained while in top gear; if a high-torque rise engine is used so that increased shifting does not occur at low speeds; and if the high speed capability of this combination is not abused.

This axle ratio reduction can effectively be used in combination with reduced engine speed so that rpms can be reduced with no change in road speed.

It should also be borne in mind that new engine drive train systems on the market can eliminate many of the problems involved in these modifications by adjusting both engine speeds and drive train components to accommodate high torque-rise engines.

Fuel consumption is lowered by a reduction in maximum governed engine speed and performance is enhanced by the increased torque characteristics of the engine and drive train. Improvements in the fuel system and turbocharger result in higher torque at lower rpm ranges. Coupled to a transmission and rear axle ratio with wide enough gear splits, this high-torque rise engine provides relatively constant horsepower over a wide range of rpms. The effect of this combination is that as engine speed goes down due to grades or winds, the driver feels that he has more power and he can thus refrain from downshifting. The increased torque and "fast" rear axles enable the vehicle to maintain road speed and keep the transmission in top gear.

Self-Steering Axles

It takes a good deal of energy for trucks to negotiate turns, and one of the devices that can make turning easier and therefore save energy, is the self-steering axle. The difference between a self-steering axle and the regular axle system is shown. Energy savings are due to reduced power requirements since tires are not being dragged sideways over the highway surface.

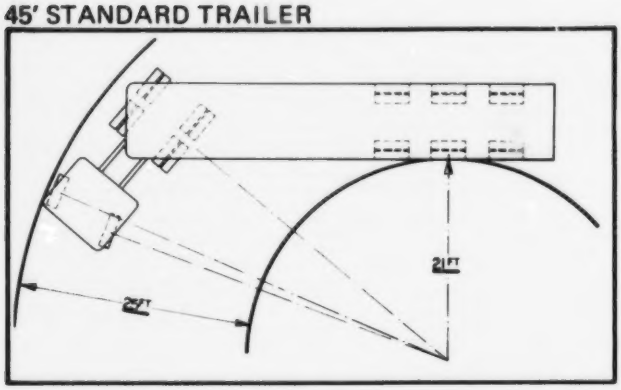
These self-steering trailers have many advantages apart from the obvious benefit of increased tire life. They can also turn more easily than standard trailers and use about 20% less road to turn. Both rear axles are steering and the trailer pivots on the axle ahead. This balanced system means reduced load shifting problems and improved turning time.

Turns are easier on the truck for another reason. In many cases on non self-steering trailers, drivers will lift the third axle in order to negotiate bends a little easier. When they do this, they overload the remaining axles, suspension, main rail and drive train. Some trucks have two or three axles that lift, operated from the tractor via an electrical solenoid.

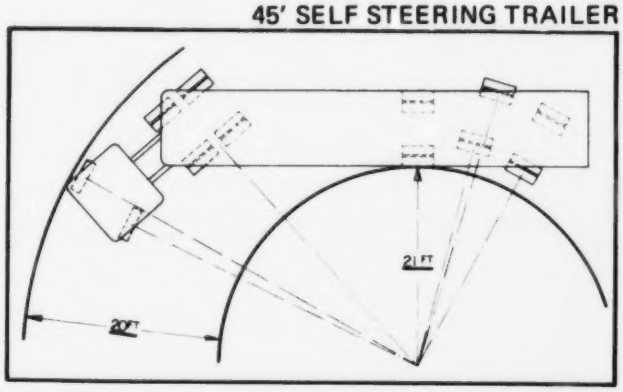
Self-steering trailers also pull more easily than fixed axle trailers. On a flat highway there can be a two to three gear advantage — meaning increased energy savings.

Negotiating turns with Standard and Self-Steering Trailers

45' STANDARD TRAILER



45' SELF STEERING TRAILER



Some provinces have legislation pertaining to axles. British Columbia has a law whereby any axle above a spread of 65" has to steer. Alberta also has legislation regarding steering axles, and Manitoba is conducting tests.

Five self-steering trailer systems are currently manufactured in volume in Canada. Some use a cable system driven by the angulation at the fifth wheel to turn an axle or combinations of axles to steer the appropriate radium required. Others use a castoring action of the wheels with air or hydraulic damping to help eliminate road shock, minimize effects due to wheel eccentricity, and provide a positive steering action. Still another system steers a complete bogie assembly with a central pivot and is driven by the angulation at the fifth wheel.

Fuel Additives

Although there are several fuel additives on the market, claimed savings should be treated with some skepticism because of a lack of controlled test data. It is possible that some additives could result in decreased fuel mileage and even damage to the engine.

Trends in energy conservation

New developments in energy conservation are already changing the nature of transportation and delivery. But how will the industry respond to even greater fuel price increases in the 1980s and 90s?

Aero Mayflower Transit Company has already designed its "Truck for Tomorrow" (see Case History section), complete with many of the fuel saving devices described earlier. But other changes, some of them quite radical, are forecast for the next two decades.

Alternative power sources

One of the biggest questions is whether new power sources will be used. Alternatives such as turbine (Brayton Cycle) and electric vehicles are now being tested, the former in over-the-road bus and truck operation and the latter in local pick-up-and-delivery. However, it is unlikely that such radical changes will be applied in substantial numbers during the 1980s.

Gas turbine engines continuously burn fuel with excess air for low emissions. The fuel / air mixture is expanded through a turbine to provide power. Fully-developed gas turbine engines are expected to offer a fuel economy advantage of almost 30% over a conventional gasoline engine in a full-size passenger car with a cost penalty of between $20 and $280 in 1974 dollars.

However, today's gas turbines still show a 20% fuel economy penalty when compared with over-the-road diesel engines in Greyhound buses. They tend to have poor idle and part-load fuel economy and may have trouble with stringent NO_x standards.

Electric powered vehicles are quite, simple, and clean. However, today's battery technology limits them to very short-range pick-up-and-delivery work. Their use may increase if petroleum prices continue to rise and

more energy is generated from coal or nuclear fuel.

Another alternative, the Stirling continuous combustion engine theoretically offers up to 47% fuel economy and could be used in cars as early as the late 1980s. Because of the relatively undeveloped state of the engine, its use in trucks is not projected until well after 1990. The Stirling is similar to a steam engine, except that it uses a gas, which is alternately cooled during compression and heated during expansion.

Changing gasoline engines.

Evolutionary changes in gasoline and diesel engines appear to be very likely for the 1980s. "Lean-burn" gasoline engines with computer controls — which reduce the fuel-to-air mixture ratio in a spark-ignited engine — provide the lowest fuel consumption for a specific driving demand, along with lower emissions. Fuel injection systems may become more widely used in conjunction with the lean burn systems. Fuel injection overcomes the carbureted system's inability to provide a uniform mixture of fuel and air to the individual combustion chambers. Fuel economy improvements of up to 10% may be possible if fuel injection were to be introduced on gasoline truck engines, depending on the efficiency of the existing carburetor.

Turbocharged gasoline engines are another trend. Turbochargers are exhaust gas driven air compressors which increase the cycle efficiency by extracting work from the otherwise discarded exhaust heat, and using it to increase the ability of the engine to deliver power by increasing the quantity of air available for combustion. If used properly, the turbocharger will also provide an increase in fuel economy by allowing a smaller, more efficient engine to replace a larger, naturally aspirated engine. Turbocharging is most effective at high engine speeds when there is sufficient exhaust gas flow to power the turbocharger and allow it to deliver maximum intake air volume. A 10 to 20% fuel economy improvement is thought to be possible.

Stratified charge gasoline engines, designed so that combustion takes place in two stages are now used in some passenger cars, and can effect a 5 to 10% fuel economy improvement over current gasoline engines. A relatively rich fuel/air mixture is ignited in a separate pre-chamber. This initial ignition then spreads to the remainder of the combustion chamber, which houses a very lean mixture, giving the effect of a very lean overall mixture.

Improving the diesel

Another desirable trend appears to be increased dieselization due to the durability, reliability and fuel economy described earlier in the book.

Diesel engines will continue to improve. New families of engines offering high torque-rise and lower governed speed are already available. These engines are all turbocharged. And it appears likely that future engines for over-the-road use will not only be turbocharged, but aftercooled for both emissions and fuel economy improvements. Possible further improvement to the basic diesel engine cycle is suggested in the so-called "bottoming cycle" — where waste heat of the exhaust is used to drive a separate Rankine cycle heat engine. The U.S. Energy Research and Development Agency has estimated a 15% increase in fuel efficiency from the bottoming cycle used to augment driveline power or to drive accessories.

Lubricants

Decreased engine and drive train friction losses can be expected through the widespread use of two improvements in lubrication.

Early problems with Molybdenum Disulfide (MoS_2) as an oil additive have now been solved, and one supplier reports that a 1% MoS_2 suspension may improve fuel economy by 3%, contribute to a reduction in sludge, varnish and wear, reduce oil viscosity increase due to oxidation, and improve cranking speed at -20 degrees Fahrenheit.

Synthetic lubricants — man-made products formed by a chemical synthesis from two or more materials — are another relatively new idea in the trucking field, and seem to have many potential energy conservation implications. They are currently being studied by the Mobility Equipment Research and Development Command of the U.S. Army (MERADCOM).

Potential capabilities include:

- Between 3.5 and 20% (cold weather) fuel savings.
- Extended oil drain intervals.

Possible Economy Measures

Item	Manufacturers' Claim	Users' Report	Independent Testing
	Figures are given as percentage of fuel saved		
Speed Limit Reduction (65 to 55 mph)	—	—	—
Improved Maintenance	—	—	14.5
Improved Driving Methods	—	—	—
Aerodynamic Aids	up to 37	16	up to 10
Fitting of Radiator Shutters	12 to 28	—	—
Variable Speed Fan Drives	4 to 10	—	—
Synthetic Lubricants	up to 31	25 to 32	—
'Doubling-Up' of Trailers	—	up to 50	—
Elimination of Unnecessary Idling	—	—	—
Conversion, Gasoline to Diesel	—	40 to 50	
Retrofit of Turbocharger	4 to 15	—	—
Turbocharger Plus Transmission/Axle Changes	up to 25.5	—	—
Fitting of Radial Ply Tires	1 to 8.5	up to 20	—
Fitting of Wide Single Tires on Drive Axles	—	—	—
Use of Single Powered Axle Instead of Dual	2.5 to 3	—	—
Derate Engine and/or Reduce Engine Speed	up to 10	—	—
Various Bolt-On Economy Devices	up to 15	13 (gasoline)	—
Fitting of Tachograph	10 or more	—	—
Avoid 'Rush-hour' Traffic on Urban Expressways	—	—	—
Rail Piggyback	—	—	—
Better Utilisation of Trailer Capacity	—	—	—
Self-Steering Trailers	up to 17	—	—

- Longer engine life.
- Reduced downtime.
- Labour savings.
- Easier winter starting and faster warmup.
- Easier disposal of used oil.

There are three types of synthetic lubricants which have been seriously considered for motor oil use:

- The polyglycol type, which is suitable, but cannot be mixed with petroleum-based lubricants.
- Synthetic hydrocarbons, which are superior to petroleum-based lubricants in low-temperature behaviour and also have some high-temperature advantages.
- Diesters of Organic Acids and Alcohols. These have capabilities desirable for potential extended-drain motor oils. They have been used in the extreme operating temperature environment of jet engines for 25 years. They have the additional advantage of being bio-degradable.

The cost of synthetic oils is currently about $13 to $14 per gallon compared to about $4 for regular motor oil. But as prices of petroleum products rise, synthetic lubricants will become more and more viable.

Other trends

It's hard to keep track of all the recent innovations in the transportation and delivery field. A miles-per-gallon indicator, developed by a supplier for use on new or retrofitted trucks, is one of the latest inventions. It should cost between $100 and $300 (U.S.).

Many of the trends build on ideas mentioned in this book — and it is clear that the transportation sector is working hard to overcome the problems of higher fuel costs.

A program for your fleet

The list of ways to save energy and money in transportation and delivery seems endless — particularly in trucking operations. Many of these improvements have been incorporated in the new truck designs. But everyone can't afford to buy new trucks. Retrofitting is the alternative, and in many cases, modifications can be very effective in achieving fuel savings. Caution, however, should be exercised when adjusting parts of the engine or drive train, since modifications to one part may mean expensive alterations to other inter-related parts.

Don't just limit your program to modifications. Educate employees to help you in your program — by driving more slowly; by going easy on the engine; by paying more attention to vehicle maintenance; by spotting areas for savings; and by loading vehicles properly.

Transportation is one of the areas in which energy-saving devices are constantly being developed and improved. Keep abreast of new developments which may provide energy savings for your fleet. In conjunction with in-plant measures, they can contribute significant savings to overall corporate objectives.

CASE HISTORIES

Canvas curtain cuts loading dock heat loss

The situation: Two large loading doors used for receiving steel coils and for loading scrap material are located in a wall of the Leigh Metal Products plant in London, Ontario. During winter, management realized that large volumes of warm plant air were being lost whenever doors were opened. Complaints were being received from employees working in adjacent areas, but because coils are delivered on flatbed trucks, there was little means of using door bumpers to effect a seal around the door when open.

Action taken: Acting on their own initiative, plant engineers had a fireproof canvas curtain made. The curtain hangs from ceiling to floor and has a transparent plastic window to allow fork lift truck drivers to see through to the other side before passing through the slit in the middle. The curtain appears to retain significant amounts of warm air in the plant area and reduces the direct flow of cold air blowing into the pressroom area.

Energy/dollar savings: No direct measurement. It was felt that some steps had to be taken. Given the low cost and the empirical evidence that heat is being saved, management is satisfied.

Cost of improvement: $2,200.

Recommendation: Look into one of the many feasible solutions for reducing heat loss through open loading dock doors. Several designs of plastic and other curtains for this purpose are commercially available. Check with your fire insurance company to make sure curtain material meets with their approval before purchase.

Diesel delivery trucks offer benefits

The situation: Labatt Brewery's Quebec operations include a fleet of more than 160 delivery vans which until late in 1975 were entirely gasoline powered. The company realized that given higher fuel costs, diesel engines would offer significant energy savings along with lower exhaust pollution, less downtime, longer warranty and a number of other benefits.

Action taken: Gasoline powered trucks in the company's fleet replaced with diesel powered trucks.

Energy savings:
Previous per truck consumption:
9,000 mi/yr. @ 4 mpg = 2,250 gals/yr.
Present per truck consumption:
9,000 mi/yr. @ 8 mpg = 1,125 gals/yr.

Dollar savings:
2,250 gals @ $.89/gal. = $2,002
1,125 gals @ $.78/gal. = 878
Per truck savings = $1,124/year

Cost of improvement: Additional cost per engine = $3,000.

Recommendation: Look to diesel engines as a source of real dollar savings when replacing existing engines or specifying new on the road equipment. As fuel prices increase, diesel engines will represent an even more attractive energy saving investment.

Among the auxiliary benefits of diesel power are: reduced maintenance costs due to elimination of spark plugs, coil, condenser, carburetor, distributor and wires and reduced overhauls due to greater engine reliability. Assuming a truck life of 8 years and a $500. higher trade-in for diesel over gasoline engines, even allowing for higher initial investment, total dollar savings for Labatt's amount to more than $6,000 per truck.

Fleet of compact cars means fuel savings

The situation: Most of the cars in the fleet used by 3M Canada's salesmen were intermediate-size — consuming more fuel than available compact cars.

Action taken: Starting in November, 1976, 3M Canada started to purchase compact cars as replacements for intermediate-sized cars as these were retired from the fleet. There is still a "mix" of cars, but the breakdown of anticipated savings follows.

Energy savings: Fuel economy (combined highway and city driving) for a compact car = 20.4 mpg; and for an intermediate car = 18.0 mpg. Average yearly mileage and gallon usage for a compact:
= 21,000 miles ÷ 20.4 = 1030 gals (U.S.).
Average yearly mileage and gallon usage for an intermediate-sized car:
= 21,000 miles ÷ 18.0 = 1166 gals (U.S.).

Dollar savings: Savings per car per year: 136 gals × 4/5 = 109 Imp. gal × 88¢/Imp. gal = $96.00
Savings over 3-year life of car ($96.00 × 3 years) = $288.00.
Savings on 224 replacement cars over a 3-year period = $64,500.00.
Average savings per year ($64,500 ÷ 3) = $21,500.

Recommendation: By gradually replacing intermediate-size cars with compacts, a company can cut down on gasoline consumption and save a great deal of money.

Gas-fired door heaters eliminated at receiving dock

The situation: At a General Motors plant, five gas-fired door heaters were used for tempering air when a number of large dock doors were open to receive trucks with raw stock.

Action taken: at a total cost of $2,100, an interior metal wall with two doors and weather curtains was installed at the edge of the receiving dock. Receiving dock sprinklers were converted to a dry system and the five gas units were disconnected.

Energy savings: Gas — 12,800 Mcf × 1.020 MMBtu/Mcf = 13,056 MMBtu
Electricity: 3600 Kwh/yr × .003413 MMBtu/Kwh = 12 MMBtu/yr
Total Btu's saved:
13,068 MMBtu = 13,068 Mcf.

Dollar savings: 13,068 Mcf @ $2.00/Mcf = $26,136/year

Cost of improvement: $2,100.

Recommendation: Consider the use of fixed walls or canvas or plastic curtains or other barriers to limit access of cold air from loading and receiving docks to the plant or warehouse floor. Loading dock shelters which reduce air flow into a heated area also represent an attractive investment. (see case history)

Lift truck tests show cost-saving potential

The situation: The Staff Services department of Kimberly-Clark of Canada Limited decided to perform tests on part of the firm's fleet of propane-powered lift trucks to determine ways of saving money.

Action taken: The project evaluated a portable carbon monoxide analyzer, diagnostic ignition analyzer and an electronic ignition system. Results showed that propane-powered fork lift trucks, equipped with catalytic mufflers and capacitor discharge electronic ignition systems require less maintenance, less downtime, less fuel and give better reliability than standard propane-powered units. Tests also pointed to the possibility that heating and ventilation costs in all of the firm's Canadian plants could be reduced, and that greater protection from fork truck exhaust emissions could be given to plant personnel.

Energy savings: Up to 20% of lift truck fuel costs. For one truck tested at the Rexdale, Ontario plant, fuel consumption was reduced by 20% or 1.58 lb./hr., and since the truck operated for 2,820 hours per year, fuel savings of 4,455 lbs/yr. would result.

Dollar savings: 4,455 lbs/yr. × $0.085/lb. (for propane) = $378.00/year.

Recommendation: Look into the possibilities of installing catalytic mufflers and capacitor discharge electronic ignition systems on propane-powered lift trucks.

Off-peak charging of lift truck batteries reduces bills

The situation: At a General Motors plant, battery chargers for electrically powered fork lift trucks had traditionally been started at the beginning of the first work shift. This practice incurred an additional electrical load at a time of peak demand and resulted in extra demand charges from the electrical utility.

Action taken: Battery charging was undertaken during the second shift — when peak demand is much lower.

Energy savings: None. However, savings on the electrical bill result from the reduction of demand charges.
Previous consumption: 400 Kw at peak demand.
Present consumption: 400 Kw during off-peak demand period.

Dollar savings: $400\ \text{Kw} \times \frac{\$2.00}{\text{Kw}} = \$800./\text{mo.}$

$= \$9{,}600$ per year.

Cost of improvement: Nil.

Recommendation: Look into the possibility of rescheduling any energy consuming activities which need not be carried out during peak electrical energy demand periods. For further reductions in demand charges, use of a peak load scheduler or "load shedder" should be investigated.

Shelters installed on loading docks

The situation: At an equipment manufacturing plant, a single loading dock was used in which 26 square feet of open area existed between an average truck and the loading dock. Given a relatively long heating season (high degree days) and a substantial differential between average inside and outside temperatures (65° and 40°F, respectively) substantial amounts of gas-fired building heat were being lost unnecessarily.

Action taken: A loading dock shelter was installed which made a tighter "fit" between building and truck and eliminated approximately 85 percent of the 500 fpm air loss.

Energy savings: Previous loss: 26 sq. ft. × 500 fpm × 40 wk/yr × 6 day/wk × 4 hr/day × 60 min/hr × .0183 Btu/cf°F × (65-40)°F = 343 MMBtu/yr.
Savings: 343 MMBtu/yr × 0.85 = 292 MMBtu/yr.

Dollar savings: 292 MMBtu/yr = 290 Mcf @ $2.00/Mcf = $584/year.

Cost of improvement: $600.

Recommendation: Estimate the energy loss through loading dock doors, particularly if your plant is subject to severe winters. Dock shelters, which come in a variety of designs, can under some conditons pay for themselves in a single heating season. Permanent and temporary walls and barriers inside the loading dock should also be investigated.

"Truck of Tomorrow" claims 35-40% fuel savings

The situation: Aero Mayflower Transit Company put its computer to work to determine whether significant fuel savings could be realized in a tractor-semitrailer moving van combination through use of components designed primarily to reduce the amount of energy required to propel the rig at speeds of 55 to 60 mph.

Action taken: The computer came up with an answer, and a rig called "Mayflower Truck of Tomorrow" was built with the following specifications:

- Air deflector.
- A vortex stabilizer to control sidewinds, attached vertically to the headwall of the trailer.
- A vane mounted on the front edge of the trailer's roof with rounded lip covering the upper edge and an air spoiler above it.

- A special diesel turbo-charged engine coupled with a six-speed transmission and 23,000 lb. drive axle with a ratio of 3.70.
- Fan clutch.
- Steel-belted radial tires mounted on 22" wheels for the tractor and 8¼-20 steel radials under the tandem trailer.
- Engine governed at 1,950 rpm and pulling the rig at 61-63 mph at 1,800 and 1,850 rpm. Top speed at 1,950 rpm is 66.8 mph.

Energy/dollar savings: The truck regularly gets 8-9 mpg — 35 to 40% better mileage than similar Mayflower trucks without the fuel-saving components.

Recommendation: Take a look at some of the many fuel-saving devices on the market and decide which ones have the most potential for your type of operation. Some measures are better for city driving, some for highway, etc.

Tips for saving energy and money in transportation and delivery

In-plant operations

1. Maintain electric lift truck motors.
2. Charge lift truck batteries during off-peak hours to save on electrical bills.
3. Equip propane-powered lift trucks with catalytic mufflers and capacitor discharge electronic ignition systems for greater efficiency.
4. Motivate F.L.T. drivers to shut off propane F.L.T. motors when they leave truck. Idling is greatest area of loss for fossil fuelled fork list trucks.
5. Install air locks on loading doors. Alternatives are fixed walls, fireproof canvas or plastic curtains and other barriers; or dock shelters on loading docks.

Savings in the use of cars

6. Convert cars in the sales fleet from large or intermediate-size cars to compacts.
7. Buy cars with smaller engines.
8. Cut down on gas-guzzling features such as air conditioning.
9. Make better use of the cars at night by allowing employees to drive the vehicles home if they form carpools.

Saving energy in trucking

10. Consider consolidating routes and making other scheduling and loading changes to make sure that trucks are being used efficiently.
11. Train drivers to be energy-conscious by doing the following:

- Not making "jack-rabbit" starts.
- Not leaving engines idling for long periods of time, even in cold weather.
- Staying 200 rpms under the governor maximum to save fuel.
- Not hitting the governor with every shift, since it takes extra fuel to go to maximum rpm with every shift.
- Keeping a light foot on the accelerator and brake pedals to conserve fuel — not hotrodding or sliding to a stop.
- Gearing down when necessary, rather than lugging. Lugging the engine takes extra fuel, and increases the likelihood of early overhauls and breakdowns on the road.
- Checking tire pressure. Keep tire pressure up —it's easier on the tires and saves fuel.
- Preventing spillage. Make sure extra fuel isn't spilled when refueling. Don't top the tank! Keep the fuel cap tightened so that fuel is not lost through evaporation or spillage.
- Staying alert and rested in order to drive safely and conserve fuel. A tired driver is erratic, doesn't shift gears when he should, and fails to hold his speed. Driving this way uses extra fuel.
- Keeping the engine tuned. An efficient powerplant burns less fuel.
- Sticking to lower speeds. Three methods can be helpful in making drivers slow down:

i. Use a road speed governor;

ii. Use of a tachograph to enforce a fleet speed limit;

iii. Motivating the driver to want to maintain lower speeds, e.g. Sharing truck mileage and fuel consumption data with drivers to encourage efforts at saving.

12. Use the right truck for the right job.
- Make sure the truck is specified correctly and that the engine is large enough.
- Don't retire power units purchased for highway operation to city use since they can't be expected to perform properly.

13. Adhere to a regularly scheduled program of preventive maintenance to prevent major breakdowns — sixty days is a good interval between tune-ups.

14. Use radial tires. They cost more than bias-ply tires initially, but the investment soon pays off in fuel economy.

15. Investigate use of diesel engines, especially in cases where trucks are used for extensive travel.

16. Consider use of aerodynamic drag reduction devices especially on straight trucks.
- Wind deflectors mounted on cab tops to deflect air flow over the top of the van or trailer;
- Vanes which turn the airflow around trailer corners;
- Rounded trailer corners and fairings mounted on the forward flat face of the trailer; and
- Gap fillers to reduce turbulence in the gap between tractor and trailer.

17. Use multiple trailer combinations to increase load space and achieve fuel economy on a productivity basis.

18. Use automatic transmissions to save fuel in local pick-up and delivery operations.

19. Use fan clutches — cooling fans don't have to operate all the time.

20. Engine and drive train modifications can also save energy. They include:
- Derating engine horsepower.
- Reducing engine speed (rpm).
- Reducing the axle ratio.

21. Automatic radiator shutters control engine temperature, and save money by adding to engine longevity.

22. Use self-steering axles to save energy used in negotiating turns.

23. Take a look at fuel additives. Some companies have found that they have a marked effect on fuel economy.

24. Consider optimizing routing in city deliveries. Often, use of computers and operations research techniques can be justified.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg\cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

Approximate Common Equivalents
1 in. = 25 mm
1 ft. = 0.30 m
1 yard = 0.91 m
1 mile = 1.6 km
1 sq. in. = 6.5 cm^2
1 sq. ft. = 0.09 m^2
1 sq. yd. = 0.84 m^2
1 acre = 0.40 ha
1 cu. in. = 16 cm^3
1 cu. ft. = 28 dm^3
1 cu. yd. = 0.76 m^3
1 quart (liq) = 1.1 ℓ
1 gallon = 4.5 ℓ
1 oz. (Avdp.) = 28 g
1 lb. (Avdp.) = 0.45 kg
1 hp (UK) = 0.746 kW
1 lbf. = 4.4 N
1 psi = 6.9 kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Thermal resistance (R value)	square metre kelvin per watt	m^2K/W
Energy density	joule per cubic metre	J/m^3

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1^\circ = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
hectare	ha	1 ha = 10 000 m^2.

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